



The Role of Water in the Development of Great Sand Dunes by Andrew Valdez

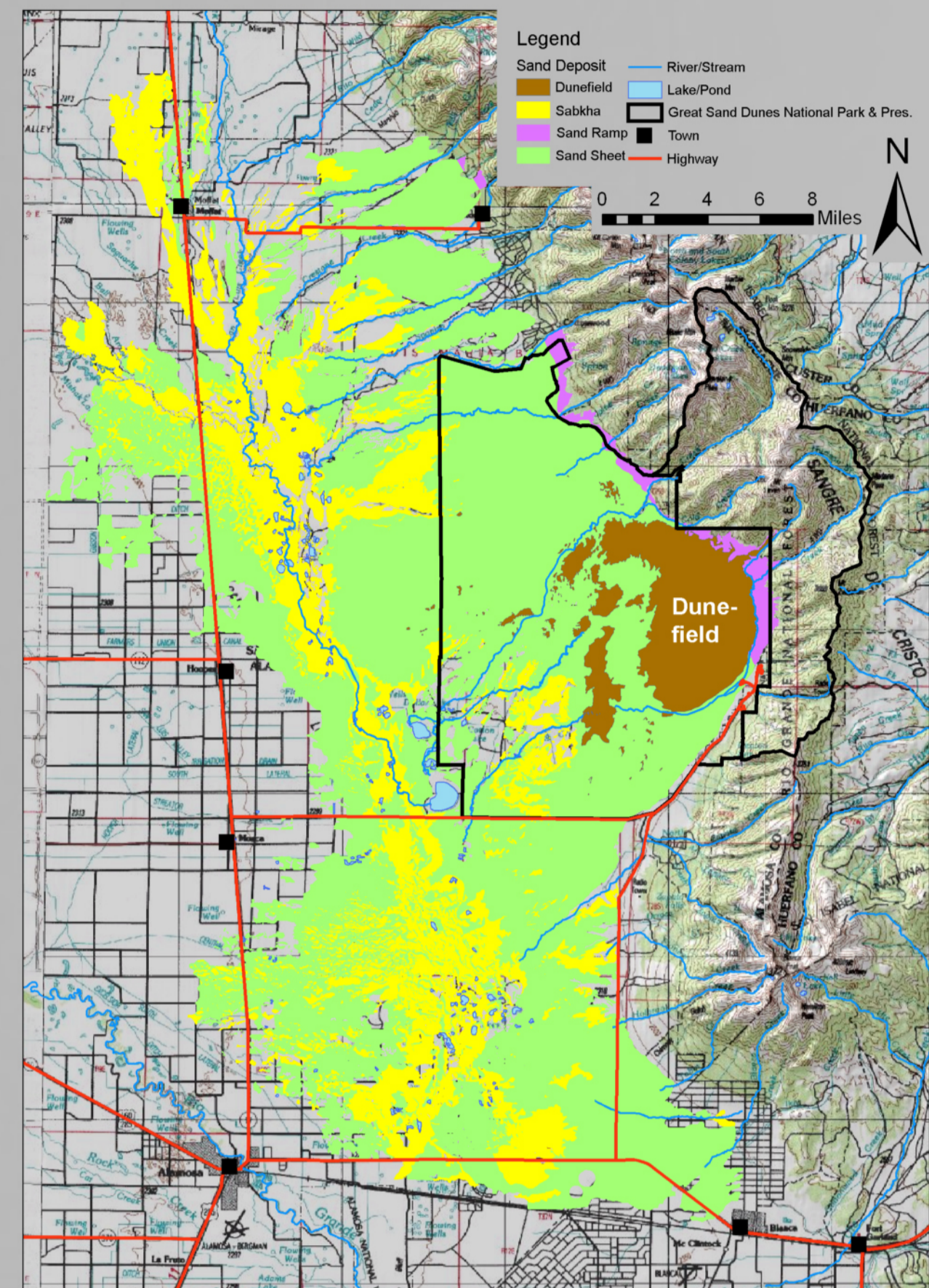


Figure 1. Sand Deposits of the northeast San Luis Valley

Introduction

The Great Sand Dunes consists of four sand deposits that cover much of the northeast San Luis Valley. (Fig. 1) The sand deposits begin in the center of the valley and change with elevation and wind energy in an eastward direction. The lowest deposit is cemented by evaporite minerals and is known as a sabkha. With a slight increase in elevation, the sand is no longer cemented and it forms a low-lying deposit that, for the most part, lacks active dunes, and is known as a sand sheet. At the base of the mountains, where wind energy is greatest, the sand is shaped into dunes forming a dunefield. The dune system ends where sand laps onto the side of the mountains, building sand ramps.

These deposits have developed in response to a number of geologic, hydrologic, and biologic processes. These processes are: rifting, sand movement by wind, sand movement by streams, vegetation growth, and evaporation of groundwater. Rifting, or the splitting of the earth's crust, creates the setting for the sand deposits. As it occurs, the crust is broken into blocks that rotate vertically. The blocks that rotate downward form the San Luis Valley. The blocks of the Sangre de Cristo Mountains are rotating upward. Since the valley is subsiding, it is a depositional basin where sediments, including sand, collect. In order to form sand deposits, a sand supply is needed and a depositional basin offers that. Wind transports sand and forms sand dunes. Another mechanism for sand transport and deposition is stream flow. Where vegetation is established, it alters wind energy by increasing surface roughness and decreasing the wind's ability to transport sand. Areas such as the sand sheet lack abundant dunes because these areas are covered by vegetation. In areas where the groundwater is near the surface, it evaporates leaving behind minerals that harden the sand into sandstone.

Because the theme of this conference is water issues, the remaining discussion will focus on how water affects the development of the Great Sand Dunes.

The Role of Surface Water

The Great Sand Dunes are located in the northern portion of the San Luis Valley where rift-related subsidence is the greatest. As a result, a large depression has formed. This is locally known as the closed basin. The primary streams that flow into the closed basin are Saguache Creek out of the San Juan Mountains and San Luis Creek from the Sangre de Cristo Mountains. During average and above average flows, these streams can reach the bottom of the closed basin, filling ponds and lakes. During very wet periods, the lakes can fill the closed basin depression and become tributary to the Rio Grande River. This was last documented to have occurred during the 1920s. Current land use now requires that most stream flow be diverted for agricultural use, so the opportunity for the closed basin to fill is diminished. Periodic input from the Rio Grande may occur since sand deposits located along the southern margin of the closed basin have a stream channel morphology and trace up gradient to the Rio Grande.

Streams play an important role in the delivery of sand to the sand deposits. The sand of the Great Sand Dunes originates in the surrounding San Juan and Sangre de Cristo Mountains. The weathering process breaks rock down into boulders and smaller fragments that can be transported by water into the San Luis Valley. Figure 2 demonstrates the area of sand transport to the Great Sand Dunes. Saguache and San Luis Creeks and their tributaries collect water in their mountain basins and flow into the valley bringing sediment with them. Coarser material, such as boulders and cobbles, are deposited in alluvial fans at the mountain

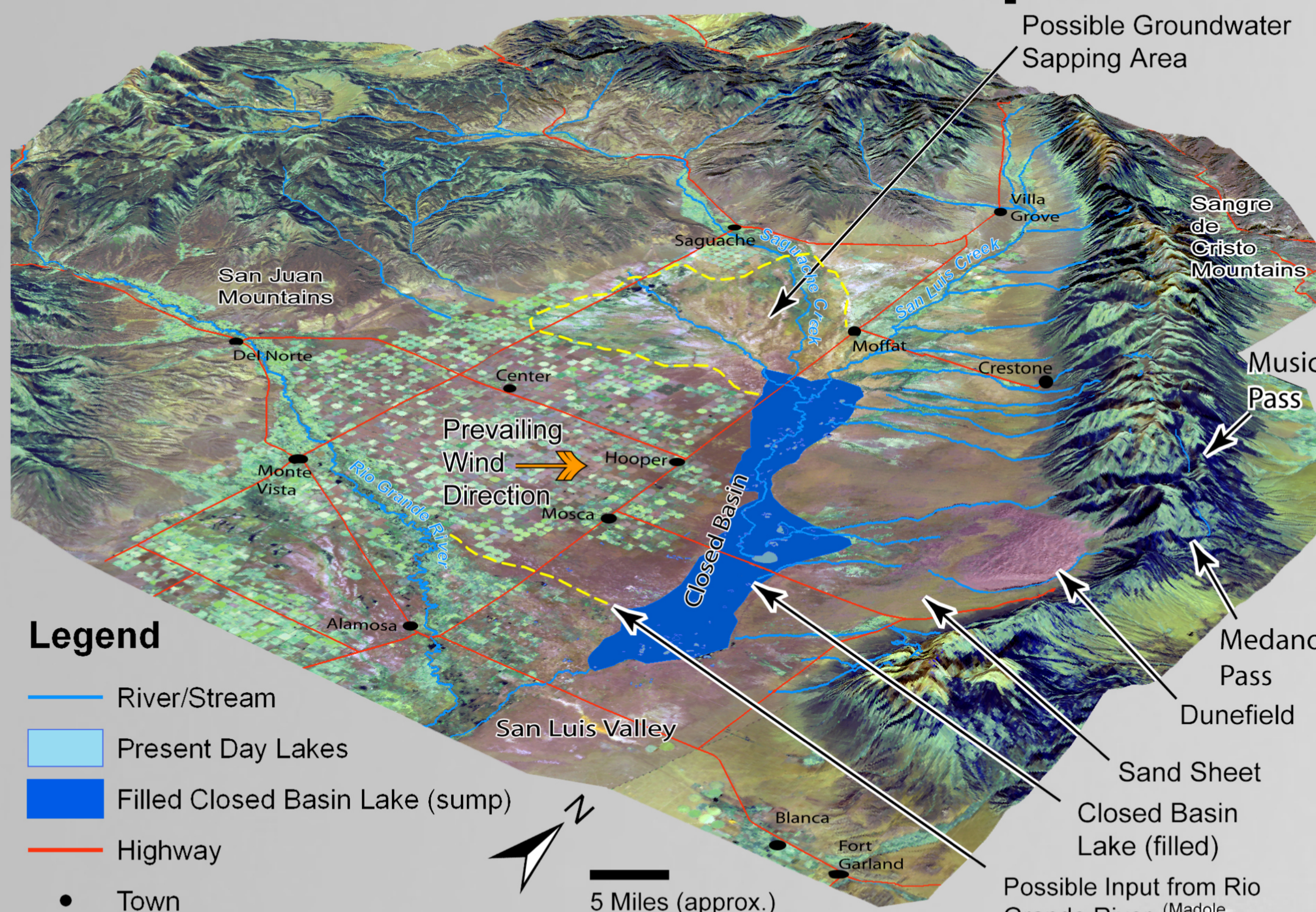


Figure 2. Sand transport from the surrounding mountains via streams into the playa lake system of the San Luis Valley.

front as stream flow slows down. Beyond that, and into the San Luis Valley, the low energy streams continue to transport sand and finer material. Once the streams reach a playa lake/pond, the sand is deposited in a delta and silt and finer material settle in the open water of the lake. Wave action can redistribute the sand forming a beach deposit. Playa lakes/ponds are temporary features that begin to dry, and then disappear as water input drops below water loss. Once dry, the former beach deposits are exposed to the wind, and can be transported by the wind. Small playas often have crescent-shaped sand ridges on their downwind side that are known as lunettes. The thickest part of the dune system is downwind of the filled playa lake, suggesting that the sand source is the playa lake system (Madole, 2002).

The dominant wind direction on the valley floor is from the southwest, therefore dunes formed from the beach deposits will migrate to the northeast toward the Sangre de Cristo Mountains. Currently some of these dunes migrate an average of 35 feet per year (Marin, 2005), (Foreman, 2006). As they approach the passes of the Sangre de Cristo Mountains, the wind patterns change from unimodal or dominant in one direction, to bimodal, or dominant in two directions. In this case, the bimodal directions are from the southwest and northeast. In this bimodal zone, dune behavior changes and the dunes stop migrating and begin to grow vertically. Along the mountain front, away from the passes, the winds remain unimodal and sand ramps form as dunes migrate up the slope.

Streams also modify the perimeter of the dunefield and help give the Great Sand Dunes their majestic character. Medano Creek flows along the east and southeast dunefield margin and Sand Creek flows along the northern margin. These streams erode sand from the upper margins and deposit it along the more distal margins of the dunefield, giving the dunefield its crescent shape. Each lobe of the crescent is built by stream-deposited sand. Medano Creek flows extensively along the margin and its effect is dramatic. (Fig. 4) The upper dunefield margin is truncated by the creek, resulting in a large slipface. The sand deposition on the southeast floods the area with sand resulting in closely spaced north-south trending dunes. The excess sand fills the troughs of the north-south trending dunes resulting in the northeast-trending ridge seen on the horizon. Edges of the dunefield that lack stream-supplied sand have much smaller dune forms.

The Role of Groundwater

The sabkhas at the Great Sand Dunes occupy the lowest elevations in the closed basin and in other areas where groundwater can be within a few feet of the ground surface. (Fig. 3) The sabkha within the closed basin depression is known as a playa sabkha, since it correlates to areas covered by playa lakes. The sabkhas outside the depressions are referred to as deflational sabkhas, since wind deflation has lowered the ground surface to near water table elevations. These areas are near stream channels where stream recharge has elevated the water table. The groundwater beneath the dune system is sourced by stream flow, with the majority of recharge occurring within five miles of the mountain front. The water table gradient along the mountain front slopes westward toward the topographic low of the closed basin. In the closed basin, the water table gradient

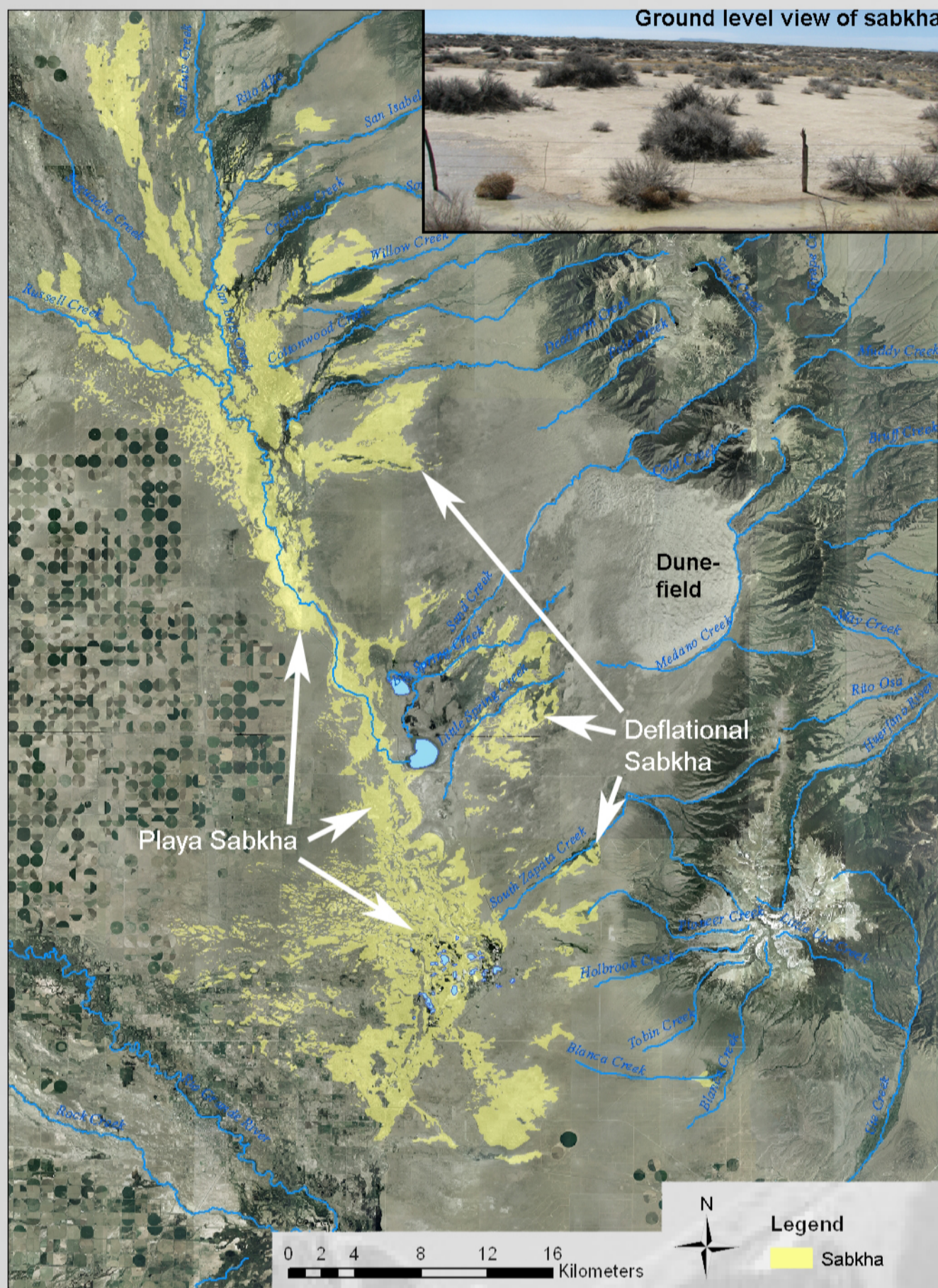


Figure 3. Location of the sabkha sand deposits.

is flat and the water no longer flows. Over time it has fully saturated the sediment and its output is via evapotranspiration. This has resulted in the water quality having a high pH due to a high salt content.

The position of the water table is critical in the formation of the sabkha. Where groundwater is at or near the surface, evaporation occurs. The evaporation removes the water, leaving the salt minerals behind. These minerals, which appear white in color and are often referred to as alkali, cement the sand together, forming a sabkha. Groundwater evaporation can occur whenever the water table is within a few feet of the surface. The evaporite mineral is often a sodium bicarbonate called trona (Dixon, 2006), a mineral very similar to baking soda.

How Water DOES NOT affect the Dunes

Much of the research at Great Sand Dunes was prompted by a water development proposal in the early 1990s from American Water Development Inc. The proposal predicted that water table levels at the former park boundary would be lowered by between 50 and 150 feet. That represented a significant change to the natural conditions and it alarmed the National Park Service (NPS) management. A science based division was formed to foster research and resource monitoring to better understand the natural system. The initial lack of understanding about the dunes system led to speculation about how lowering the water table would affect the dunes. One theory that became popular is paraphrased below: "The dunes at Great Sand Dunes are stabilized by moist sand found in the subsurface. That moisture comes from groundwater. If the water table is lowered, the dunes will dry up and blow away."

This theory was accepted by NPS staff and became popular in the press and in park literature. Unfortunately, it is entirely incorrect and can be quickly dismissed by comparison to other dunefields. It is already well known that wind patterns affect dune behavior. Where the wind is unimodal, dunes migrate. Where the wind is bimodal or complex, the dunes oscillate and grow vertically. This is true at the Great Sand Dunes and for other dunes systems throughout the world. In southern California, there exist dunes that are completely dry, yet they are as stable as are the large dunes at Great Sand Dunes. Along the Oregon coast there are dunes that have a higher moisture content than the dunes at Great Sand Dunes, yet they migrate. In each case, the dunes respond to wind patterns, and not to whether their core is moist or dry. Moist sand can affect sand migration, but the sand surface has to be wet. This is important along beaches where waves can keep the sand wet. In desert dunes, the barren sand surface is almost always dry and the sand is available to be transported by the wind. Additionally, the sand moisture has been measured to come from precipitation and not the ground water, which, in some cases, is 1,000 feet below the surface. Furthermore, the moisture on each grain of sand is water that clings to the grain and gravity cannot remove it. The water's surface tension that binds it to the sand grain is



Figure 4. Edges of the dunefield modified by Medano Creek.

stronger than the gravity that pulls excess water downward. Therefore the position of the water table will not cause the sand to dry. Drying that sand would require that the earth's gravitational field increase in strength. Finally, as the dunefield is in a bimodal wind area, the dunes will not blow away if they should suddenly "dry up." The multiple wind directions would continue to keep them in place.

Conclusion

Water plays an important role in the development of the Great Sand Dunes. Streams carry sand into the San Luis Valley. Where the streams create lakes, the deposition along shorelines and wave action concentrate the sand, separating it from finer-grained material. Once the lakes dry, the sand is exposed to wind, thereby giving rise to the Great Sand Dunes dune system. Stream erosion and deposition along the perimeter of the dunefield lead to the massive dune forms that visitors marvel at. Groundwater evaporation leads to the precipitation of salts that form the unusual sabkha environment.

The presence of water is often associated with high levels of biological diversity. At the Great Sand Dunes it also leads to greater diversity in the physical system. Using good science to understand the role of water at Great Sand Dunes has helped the National Park Service manage and protect Great Sand Dunes National Park and Preserve. This includes evaluating potential treats, such as groundwater withdrawal, expansion of the National Park Service boundary to protect the entire system (the previous boundary protected only the dunefield), and the ability to interpret the dunes to the public with greater depth and accuracy.

References

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